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NANNOFOSSIL BIOSTRATIGRAPHY AND FACIES ANALYSIS OF THE UPPER CRETACEOUS-PALEOCENE SEDIMENTS IN SOUTHERN EGYPT

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ABSTRACT

This paper deals with the biostratigraphic significance of nannofossil species recorded from some Upper Cretaceous - Paleocene rocks in Southern Egypt. Careful study of these calcareous nannoflora and their stratigraphic occurrences have resulted in precise dating of the different rock units, and in further refinement of the nannobiozonal schemes still vaguely defined in Egypt. Six nannobiostratigraphic zones might be established, arranged from the base to top as; *Quadrum trifidum* Zone (Campanian-Maastrichtian), *Arkhangelskiella cymbiformis* Zone (early-middle Maastrichtian), *Lithraphidites quadratus* Zone (middle-late Maastrichtian) and *Nephrolithus frequens* Zone (most late Maastrichtian). The *Markalius astroporus* and *Cruciplacolithus tenuis* Zones are of Early Paleocene age.

Such Late Cretaceous-Paleocene nannobiozones are easily equated with the planktonic foraminiferal *Contusotruncana fornicata* Zone, *Gansserina gansseri* Zone and *Globotruncana esnehensis* Zone of

the same succession. The *Globanomalina compressa / G. daubjergensis* and *Praemurica uncinata* Zones capping the whole succession.

Eight microfacies associations are described. They were accumulated under variable conditions. They started with multicolored shales reflecting shallow and stagnant or toxic bottom conditions, followed by lacustrine environment where by phosphatic remains, organic granules and rounded bodies were allowed to settle down. Next to this phase, deepening took place and resulted in the formation of fine grained calcareous deposits.

INTRODUCTION

The Upper Cretaceous – Lower Tertiary succession is one of the most spectacular and widely distributed sequences in Egypt. It covers vast areas within the frame of the Western Desert, Nile Valley, Eastern Desert and Sinai Peninsula. However the stratigraphy and Paleontology of these sediments have attracted the attention of many workers since the early days of geological investigations in Egypt.

In Upper Egypt and around the Nile Valley, the classic Maastrichtian – Paleocene section is that of Gebel Owaina, south-east of Esna, while the most famous Upper Cretaceous – Lower Eocene section is that of Gebel Duwi, Quseir, Red Sea Coast. Such profile extends to the west in Western Desert by Gebel Um el Ghanayem, Kharga Oasis and to the north in the Eastern Desert by Esh el Mellaha Range (for location, see text – Fig. 1). The succession as a whole is mostly developed in a shale and marl facies with few limestone interbeds. It is capped by a thick sequence mainly composed of limestones and dolomites. The litho- and bio-stratigraphy of such an area have been described in general terms by Beadnell (1905). He assigned the Esna shales to the "passage beds"

between the well dated Lower Eocene limestone with flint and the underlying Lower Cretaceous (Danian) chalk. This was followed by some investigations advocating the absolute conformity between the Late Cretaceous and Early Tertiary in Southern Egypt in general.

In more recent times, Youssef (1954) described Gebel Owaina section, introducing some micro and megafossils separated from its different units. He assigned the shale succession overlying the phosphate beds to the Maastrichtian, while it's upper part and the overlying chalk to the Danian. The Esna Shale was given the age of Paleocene and the overlying hard limestones, with Nummulites & Operculines of Early Eocene. He considered the sequence at Gebel Owaina to be conformable throughout. Nakkady (1957) carried out an extensive study on the foraminifera of Late Cretaceous – Early Tertiary sections from widely separated areas in Egypt and their stratigraphic relationships. He considered the Chalk and the overlying Esna Shale to be conformable and the Cretaceous – Tertiary contact lies at different levels in different sections. Again, he reviewed the biostratigraphy of the Upper Senonian and Paleocene, trying to correlate them with corresponding units in different parts of the world. He stressed on what he described as Campanian, Maastrichtian, Danian & Montian. In 1958, Nakkady applies these age assignments to the Gebel Owaina section and ascribes the shales underlying the Chalk and the Chalk units to the Danian, and the Esna Shale and the overlying hard limestone units to the Montian. An unconformity was suspected through his "Lower Esna Shale" marking the Maastrichtian – Danian boundary.

Said (1961) gave the results of his studies in Gebel Owaina section, pointing out that the lower shale unit, equated with his newly

introduced formational name of the Dakhla Shale is of Maastrichtian age in its lower part and of Lower Paleocene age in its upper part. The Esna Shale was given an Upper Paleocene. A further discussion on the Dakhla Shale and Esna Shale "Sharawna Shale and Owaina Shale of El-Naggar 1966" at the type locality of the Esna Shale in Gebel Owaina, their distributions, lithological variations and their age was given by Said (1962-1990), El-Naggar (1966, 1970).

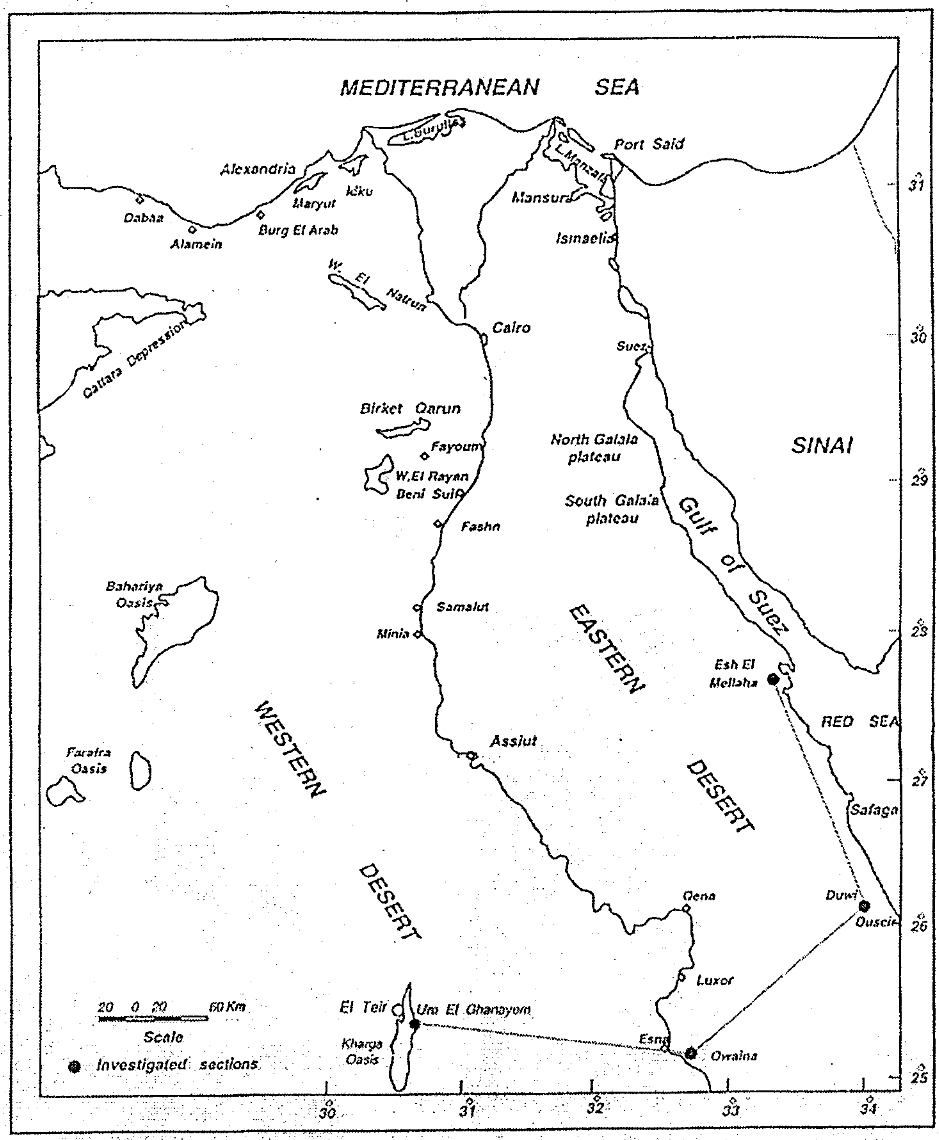
Recently, the accumulation of knowledge has emphasized the value of planktonic foraminifera as guide fossils for stratigraphical zonation, for regional as well as world-wide correlation. The most important microbio-zones are those developed in the Gulf and Atlantic Coastal Plains (Loeblich & Tappan, 1957), in Trinidad (Bolli, 1959), in Paderno d'Adda section, Italy (Bolli & Cita, 1960), in general (Bolli, 1966) in Southern Egypt and Libya (Berggren, 1964, 1969), in the Nile Valley, Egypt (Said & Sabry, 1964, El-Naggar, 1966, Beckmann et al., 1969) and in Passagno section Italy, (Luterbacher, 1975). However, the nannoflora which coexist with foraminifera should be identified and used to interpret the stratigraphy of the succession. Moreover, the stratigraphical ranges of the nannoflora could be established in the light of the planktonic foraminiferal zonation, thus ending a long controversy about their ranges.

A number of localithies in Europe and America were thoroughly studied for their nannofossils and the results have been quite affectivity used for stratigraphic purposes. Particularity useful range charts have been presented in the last twenty years by many authors. Among them, Martini must be singled out for his notable contributions on the nannopaleontology and nannobio-stratigraphy of the Cretaceous –

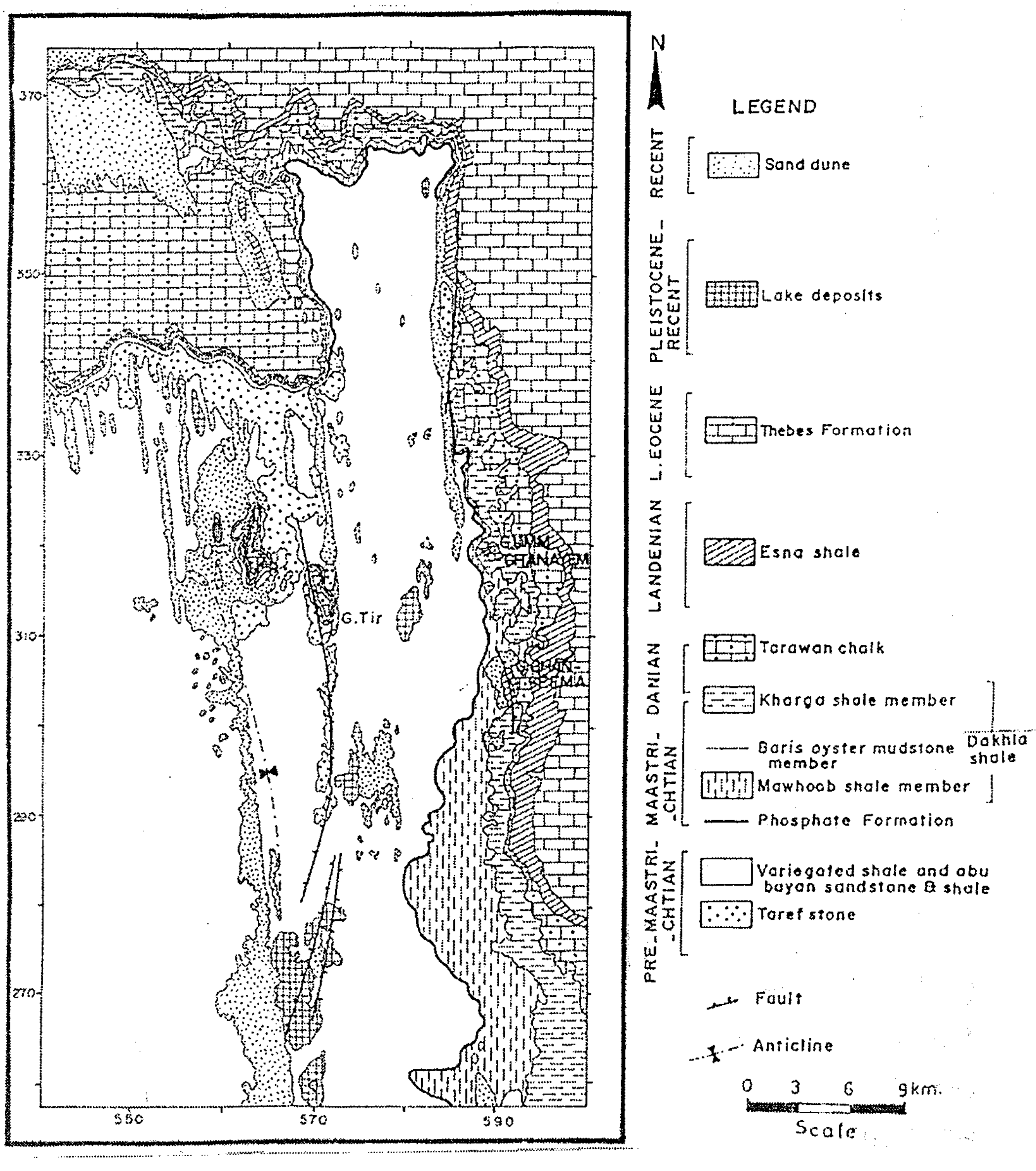
Tertiary succession. In a series of publications (1961-1976), Martini described and commented on the stratigraphic value of the calcareous nannoflora. The most useful investigations along this line are those by Stradner (1961, 1963), Bramlette & Sullivan (1961), Bramlette & Martini (1964), Sullivan (1964), Hay & Mohler (1967); in Hay et al., (1967), Reinhardt (1966), Radomski (1968), Perch-Nielsen (1968-1972), Haq (1971), Bukry (1973), Proto Decima (1974), Proto Decima, Roth & Todesco (1975), Haq & Lohmann (1976), Perch-Nielsen (1985) ...... and some others.

In Egypt, El-Dawoody made his introduction to calcareous nannoplankton through work being done in the Geological Survey of Austria during his attendance the Post Graduate Training Course in Geology 1968/1969 in Vienna, Austria. He gave the first information on the occurrence of calcareous nannoplankton from Duwi Range, near Quseir. In 1970, he studied the microbiostratigraphy of some sections from Upper and Lower Egypt with special emphasis on calcareous nannoplankton. This was followed by different investigations toward this goal, the following are worth mentioning; Kerdany (1970), Shafik & Stradner (1971), El-Dawoody & Barakat (1973), Perch-Nielsen et al. (1974), El-Dawoody & Zidan (1976), Sadek & Teleb (1978), Faris (1985, 1995) and last but not least El-Dawoody (1975 – 2002).

This work deals with the nannobiostratigraphy of the Upper Cretaceous – Paleocene sediments in Gebel Um el Ghanayem, Western Desert, Gebel Owaina / Gebel Duwi sections and Esh el Mellaha Range, Eastern Desert, Southern Egypt. It is an attempt to introduce well established biozones that could be followed in future research work around the Nile Valley and generally allover the Egyptian Territory.



Text - Fig.1 LOCATION MAP



Text Fig. 2 GEOLOGICAL MAP OF THE KHARGA OASIS (AFTER AWAD AND GHOBRIAL. 1965)

The present study aims to redefine the well known rock-stratigraphic and biostratigraphic units and to establish more precisely their true stratigraphic relationships. A brief discussion to both formational and formal zone names proposed by different authors is introduced. The biostratigraphic subdivisions and their correlation with comparable successions in other parts of the world are also achieved.

Methods of Investigation:

The Upper Cretaceous-Paleocene succession encountered in Southern Egypt is well demonstrated by four surface sections (text - Fig. 1):

(1) Gebel Um el-Ghanayem, Kharga Oasis. Such an Oasis was geologically mapped (after Awad & Ghobrial, 1965) and only small reproductions of the maps are presented here (text – Fig. 2) to show

the distribution of the various rock units and location of the section studied (approx coord.: Lat. 25° 34'N – Long. 30° 44'E). Ten samples were chosen to represent the Duwi Phosphate and Dakhla Shale formations. Fig. 1 represents a columnar section of the Upper Cretaceous – Paleocene Succession at Gebel Um el Ghanayem, Kharga Oasis, Egypt.

(2) Gebel Owaina, Nile Valley: A conspicuous hill lies about 20 kms south-east of Esna on the eastern side of the Nile (approximate coordinates: Lat 25° 15'N-Long 32° 48'E). Twenty four samples were collected from the Duwi Phosphate, Sharawna Shale and Owaina Shale units representing the succession.

(3) Gebel Duwi, Red Sea Coast: A conspicuous range lies ten kilometers, west-north-west of Quseir on the Red Sea Coast (approximate coordinates: Lat 26° 09'N-Long 32° 48'E). Twelve samples were collected from the two rock stratigraphic units constituting the succession namely, the Duwi Phosphate and Dakhla Shale formations.

(4) Esh el-Mellaha Range (Gebel Tarboul), Gulf of Suez Region: (Lat 27° 55'N-Long 33° 15'E) Ten samples were chosen to represent the Duwi Phosphate and Sudr Chalk formations. Text-Fig.1 represents a location map of the Tarboul section and also of most of the Upper Cretaceous-Lower Tertiary sections of the Gulf of Suez Region and the Red Sea Coast.

LITHOSTRATIGRAPHIC REVIEW

The Upper Cretaceous-Lower Paleocene succession in the sections studied in Southern Egypt is naturally divided into three rock stratigraphic units. These units are easily recognizable in the field dealing mainly with the lithological characters, their extent, their stratigraphic relationships and variation in facies briefly introduced here and arranged from the base upwards as:

1- Quseir Variegated Shale & Nubia Sandstone

The term "Nubian sandstone" was first introduced into Egyptian stratigraphy by Russegger (1837) after the type locality Nubia in southern Egypt. This lowermost sandstone unit was recognized by Youssef (1957) in the Quseir area as a formation and was named the "Nubia Sandstone".

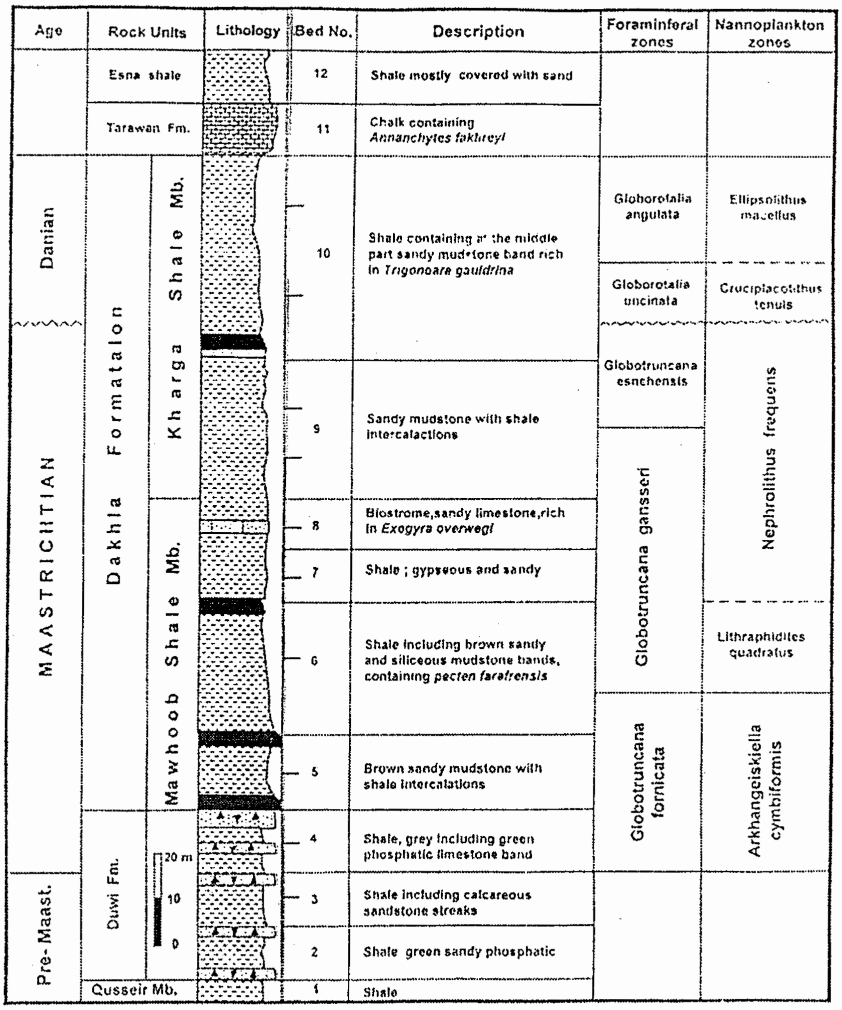


Fig.(1) Columnar section at Gebel Um el Ghanayem (Upper Cretaceous – Paleocene Succession), Kharga Oasis ,Egypt.

Wherever the base is exposed, the transgressive Nubia sandstone beds rest unconformably over the Basement rocks. The sandstone beds of this formation occupy many of the topographic lows in the general Quseir area and are especially striking at the gap south of Gebel Duwi.

The sandstones are mainly cross-bedded, sometimes parallel bedded, variegated brownish to yellowish white, violet with thin ferruginous bands. These sandstones are unfossiliferous, medium to fine grained, well sorted and occasionally conglomeratic especially in contact with the underlying crystalline rocks. The thickness of those sandstones amounts to 200 mts. at Gebel Duwi.

The Nubia sandstone is overlain by a series of unfossiliferous variegated shales and clays. Mainly composed of multicolored shales intercalated by fine-grained sandstone bands at the base. The color varies from greenish grey to green, blue, sometimes reddish brown.

These shales are invariably considered by older authors as a part of the Nubia sandstone unit. Ghorab (1956) considered the variegated shales overlying the Nubia sandstone and underlying the lowermost phosphatic bed in the Quseir area as a separate formation and named it the "Quseir Formation". Youssef (1957) studied these shales and introduced the name "Quseir Variegated Shales" for the same formation. According to Youssef, this formation is of Campanian age. The thickness of these shales reaches to 150 mts. at Gebel Duwi. These shales are somewhat similar in lithology and color to the overlying shales containing the phosphate bands.

2- Duwi Phosphate

A succession of phosphatic lenticular bands, shales, marls and limestones overlies the Quseir variegated shales with a general

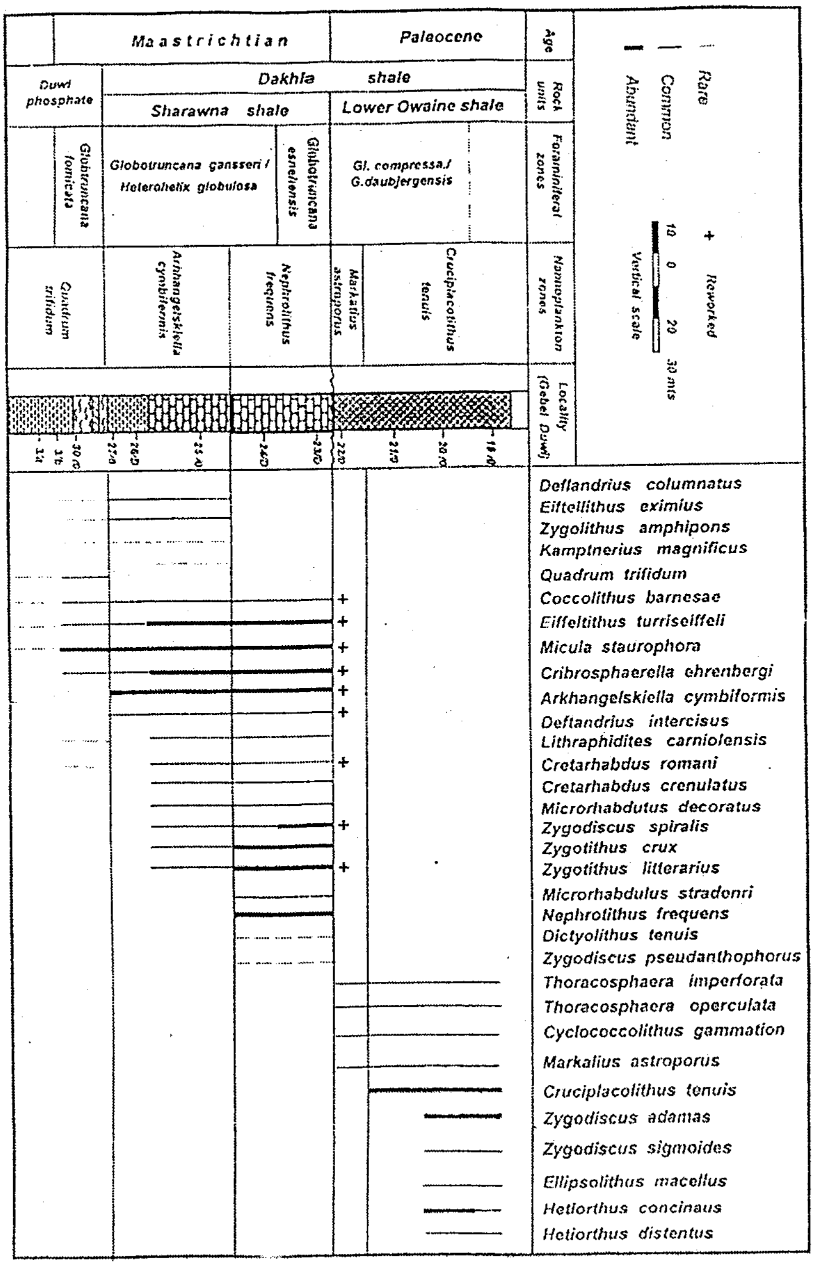


Fig.(2) General Distribution and Frequency Chart conformable relationship. In Quseir, this formation is given the name "Duwi Formation" by Youssef (1957).

El-Naggar (1966) considered similar phosphate deposits in the Esna – Idfu region as a formation and named it the "Sibaiya Phosphate" which is comparatively much reduced in thickness (not exceeding 10 mts.). In El-Naggar's opinion, this phosphate, either represents a dwarfed "Duwi Formation" or corresponds only to a part of that formation.

The Duwi phosphate formation extends in a conspicuous scarp for about 40 kms. long on the western side of Duwi range, underlying the "Dakhla Shale Formation" with *Pycnodonta vesicularis* Zittel and *Pecten farafrensis* Zittel. It crops also to the north, northwest and south of Gebel Duwi, attaining a thickness of about 150-170 mts.

The phosphate bands can be grouped into at least three horizons; top phosphatic bed (bed No. 9), middle phosphatic bed (bed No. 6) and lower phosphatic bed (bed No. 4). Here, the uppermost phosphatic rock is dark grey in color and has some silicified phosphatic remains in the form of plates, nodules and rounded bodies, embedded in a calcareous matrix. It exists within yellowish marl intercalations separated from the middle phosphatic bed by chalky and siliceous limestones with *Arca (Trigonarca) multidentata* Bullen – Newton, *Lopha villei* (Coquand), *Lopha forgemoli* (Coquand) & *Libycoceras ismaeli* Zittel. On the other hand, the middle and lower phosphatic beds intercalate with calcareous shale and clay increasing gradually in calcareous matter to the uppermost phosphatic bed.

3- Dakhla Shale

On top of the Duwi phosphate formation follows the Dakhla shale which is of wide geographical extent, and could be traced along the stable shelf of Egypt from the southern Oases in the west to Quseir district in the east. It could be also traced along the western scarp of the Nile and southwestward along the Kurkur - Dungul stretch. These shales are described by Said (1961), with its type locality, along the scarp north of Mut, Dakhla oasis. They are formed of yellowish, to grayish shales becoming marly at base and attaining a thickness of 130 mts. at its type locality.

In Kharga, the unit is divisible into a lower marly to calcareous unit with abundant *Exogyra overwegi* termed by Zittel (1883) as the "Overwegischichten" and an upper shale unit termed the "Aschgraue Blatterthone". Hume (1911), and some of the modern authors (Nakkady, 1957; Youssef, 1957) termed this unit "Lower Esna Shale". This unit is equated with both the Sharawna shale formation and the overlying lower Oweina shale Member of El-Naggar (1966). It matches also with both the Dakhla marl formation and the overlying lower Esna shale member of Abd El-Razik (1968).

The Dakhla shales are of remarkably constant lithological characters. Sometimes, it changes laterally in facies, almost entirely or at least in part to chalk or chalky limestones as in the Farafra area, Abou Minqar district and north Wadi Qena. This variation was pointed out by Kerdany (1969) and he called it as the "Khoman Chalk". This formation may be equated with the "Sudr Chalk" formation of Ghorab (1961).

The Dakhla shale unit assumes a thickness of 150-170 mts. at Gebel Duwi (Fig. 2), while it attains around 140-160 mts. at Gebel

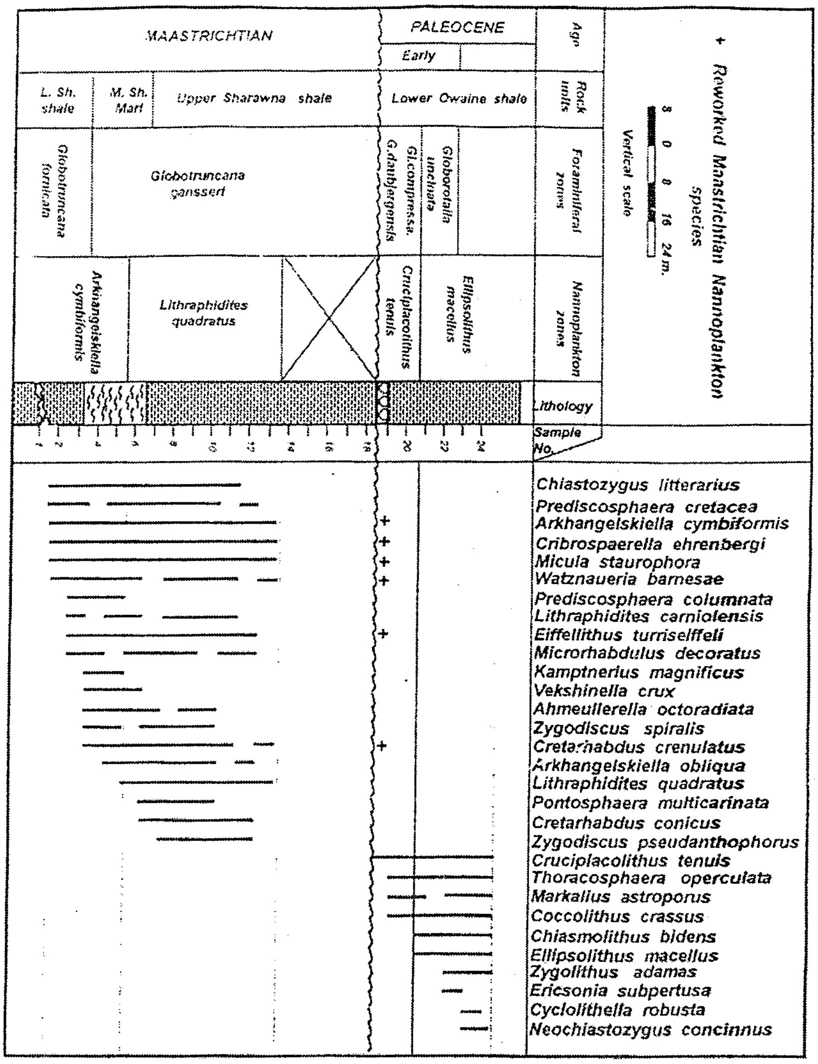


Fig.(3) Distribution of the most common Calcareous Nannoplankton species in the Maastrichtian - Paleocene of Gebel Owaina

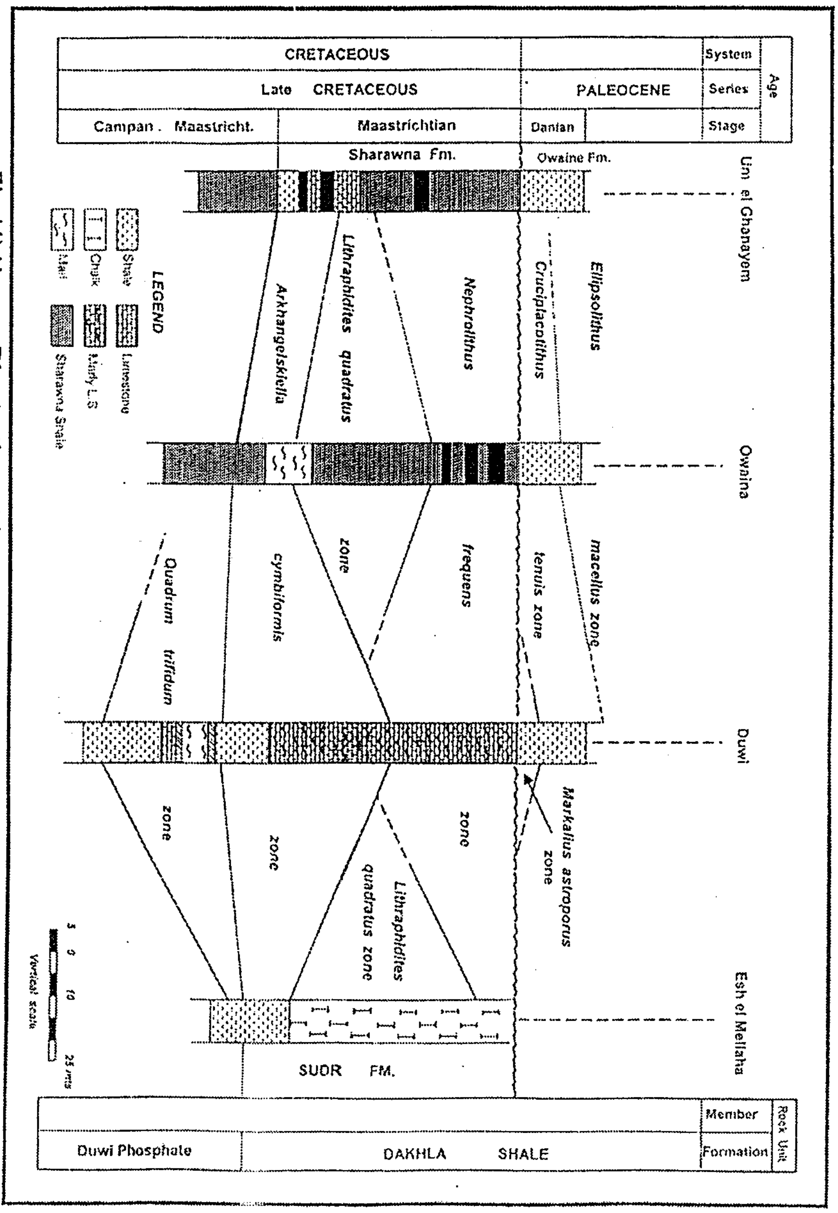


Fig.(4) Nanno-Biostratigraphic correlation chart of the Upper Cretaceous – Paleocene Succession in Southern Egypt.

Owaina but with a characteristic conglomeratic bed (sample, No.19/Ow. exceeding 2.5 mts. in thick.) (Fig. 3).

BIOSTRATIGRAPHIC ZONATION

The oldest fossiliferous rocks in the studied sections are those of the major part of Maastrichtian at Gebel Duwi. This succession overlies the phosphate beds that contain some minute forms of foraminifera which couldn't be identified with certainty. The calcareous nannoplankton content, on the other hand, seems to be rare, sometimes common but without diagnostic forms except for *Quadrum trifidum* (Stradner).

The biostratigraphic zonation proposed here for the Late Cretaceous – Early Paleocene succession is based on a system of zonation using the calcareous nannoflora. Rich assemblages with highly distinctive nannofossils have been described from a number of horizons and some of those formal zone names already in common usage have been applied to this interval. This leads to establish an interregional correlation for the Campanian / Maastrichtian – Paleocene succession of the classic sections investigated. The recorded flora build up the frame-work of this trial, substantiate with other stratigraphic tools.

In the scheme of zonation proposed, in the present study, the rule of priority has been applied whenever possible, so that the term *Ellipsolithus macellus* zone is used. to define the strata bearing the assemblage characterized by the first occurrence of *Ellipsolithus macellus* (Bramlette & Sullivan) as intended by Martini (1971) but ranging to include the *Fasciculithus tympaniformis* zone of Mohler & Hay (in Hay et al., 1967). The complex double and triple names which have been proposed are replaced by simpler terms containing the name

of a single fossil. Such a trial offers a means for a transoceanic correlation of the Egyptian sections with reference sections elsewhere. Most of the zones known here are again concurrent range zones based on the appearance or disappearance of a particular species.

Sixty two species of calcareous nannoflora were recognized in the outcrop samples of Duwi/Owaina sections, Eastern Desert, Egypt. Thirty two species from Gebel Duwi and thirty species from Gebel Owaina (fourteen species of which encountered in the U. Cretaceous – Paleocene of Gebel Owaina) were known to characterize their stratigraphy, identified and fully described by El-Dawoody (1978). The most-common species of which are given in two general distribution charts; the first is concerned with the Campanian / Maastrichtian – Paleocene nannofossils of Duwi section (Figure 2) and the second represents the Maastrichtian – Paleocene nannofossils of Owaina section (Figure 3). Within this frame, the present author proposes the following calcareous nannoplankton zones for the Late Cretaceous – Early Paleocene deposits of the region under investigation:

1- *Quadrum trifidum* Zone:

This zone lies at the base of the Maastrichtian succession in Gebel Duwi just underlying the *Arkhhngelkiella cymbiformis* Zone. It is defined here by the full range of *Quadrum trifidum* (Stradner), its lower boundary is unclear that is due to the presence of an intraformational conglomerate. It spans the interval from the first occurrence of *Quadrum trifidum* (Stradner) to the level of appearance of *Arkhangelskiella cymbiformis* Vekshina at the Campanian - Maastrichtian boundary Roth (1973) described a total range zone of *Tetralithus trifidus* (= *Tetralithus gothicus*), which in the Kef section, Tunisia (Verbeek, 1977) extends higher than our *Tetralithus gothicus* (partial range) Zone. Our zone

probably coincides with the lower part of the *Arkhangelskiella cymbiformis* Zone. The most-common and diagnostic species are:

***Coccolithus barnesae* (Black)**
***Cribrosphaerella ehrenbergi* (Arkhangelsky)**
***Eiffeltithus turriseiffeli* (Deflandre)**
***Micula staurophora* (Gardet)**
***Quadrum trifidum* (Stradner)**

This zone is equated with the lower part of the *Globotruncana fornicata* zone of Campanian-Maastrichtian age in Gebel Duwi.

2- *Arkhangelskiella cymbiformis* Zone:

This represents the lowest recognized calcareous nannoplankton zone in Owaina section. It is recorded in the uppermost part of Lower Sharawna Shale together with the major part of Middle Sharawna Marl members of Gebel Owaina, assuming a thickness of around 16 meters. Such members are distinguished by the first flood of *Arkhangelskiella cymbiformis* Vekshina, after which this zone is coined. It is usually associated with multiple of calcareous nannoplankton species that characterize the Maastrichtian in many parts of the world, including the type Maastrichtian of Holland (Bramlette & Martini, 1964). The most-common and diagnostic species are:

***Ahmuellerella octoradiata* (Gorka)**
***Arkhangelskiella obliqua* Stradner**
***Chiastozygus litterarius* (Gorka)**
***Cretarhabdus crenulatus* Bramlette & Martini**
***Cribrosphaerella ehrenbergi* (Arkhangelsky)**
***Eiffellithus turriseiffeli* (Deflandre)**
***Kamptnerius magnificus* Deflandre**
***Microrhabdulus decoratus* Deflandre**
***Micula staurophora* (Gardet)**
***Prediscosphaera columnata* (Stover)**
***Prediscosphaera cretacea* (Arkhangelsky)**
***Vekshinella crux* (Deflandre & Fert)**
***Watznaueria barnesae* (Black)**
***Zygodiscus spiralis* Bramlette & Martini**

The zone under investigation may be correlated with *Tetralithus nitidus trifidus* zone of Bukry & Bramlette (1970), following them Cita & Gartner (1971) in the North Atlantic. The equivalent of the latter zone under the name *Tetralithus gothicus trifidus* zone was previously traced by Perch-Nielsen et al (1974) in the Nile valley, Egypt, the same locality of the present work. They applied such zone to the lowest part of their succession irrespective to the first appearance of the nominate species clearly shown by Roth & Thierstein (1972). In Gebel Owaina, the *Arkhangelskiella cymbiformis* zone coincides with the upper part of the planktonic foraminiferal *Globotruncana fornicata* zone together with the lowermost part of *Gansserina ganaseri* zone denoting an Early – Middle Maastrichtian age. The boundary of such zone is marked by the first occurrence of *Lithraphidites quadratus* Bramlette & Martini.

3- *Lithraphidites quadratus* Zone:

This zone is met with in the next 32 meters within the upper most part of Middle Sharawna Marl together with the major part of Upper Sharawna Shale members just overlying the *Arkhangelskiella cymbiformis* zone in Gebel Owaina. It is defined here by the first occurrence of *Lithraphidites quadratus* Bramlette & Martini and corresponds to the full range of that marker species. The upper boundary of this zone is not well defined. Such zone is characterized by a calcareous nannoplankton assemblage, rich in species common in the *Arkhangelskiella cymbiformis* zone but without *Kamptnerius magnificus* Deflandre and *Prediscosphaera columnata* (Stover). Beside the distinctive marker species of the zone, the following species are also recorded:

Cretarhabdus conicus Bramlette & Martini
Lithraphidites carniolensis Deflandre
Pontosphaera multicarinata (Gartner)
Zygodiscus pseudanthophorus Bramlette & Martini

The *Lithraphidites quadratus* zone was first introduced by Cepek & Hay (1969) at its locality in Wilcox County, Alabama. It was defined as the interval from the first occurrence of *Lithraphidites quadratus* Bramlette & Martini to the first occurrence of *Nephrolithus frequens* Gorka. The definition of this zone as used here differs from that given by Cepek & Hay due to the lack of the nominate taxa characteristic to the top boundary of such zone. In Gebel Owaina, this zone spans the major upper part of the planktonic foraminiferal *Gansserina gansseri* zone both of Middle - Late Maastrichtian age. It matches with the upper part of *Arkhangelskiella cymbiformis* zone previously known by El-Dawoody (1970) and El-Dawoody & Barakat (1973) in Duwi Range, Red Sea Coast. Again the *Lithraphidites quadratus* zone represents the youngest Maastrichtian nannofossil zone in Owaina section.

4- *Nephrolithus frequens* Zone:

This zone caps the Maastrichtian succession in Gebel Duwi just overlying the *Arkhhngelkiella cymbiformis* Zone. It is defined here by the full range of *Nephrolithus frequens* Gorka, its lower boundary is unclear that is due to the presence of an intraformational conglomerate. It spans the interval from the first occurrence of *Nephrolithus frequens* Gorka to the level of extinction of most Cretaceous species at the Cretaceous-Tertiary contact (Cepek & Hay, 1969). The late Maastrichtian of the type section belongs to the *Nephrolithus frequens* Zone, and has been shown to occur mainly in high latitudes Upper Maastrichtian (Martini & Worsley, 1971). The most-common and diagnostic species are:

Chiastozygus litterarius (Gorka)
Cretarhabdus conicus Bramlette & Martini
Lithraphidites carniolensis Deflandre
Microrhabdulus decoratus Deflandre

Nephrolithus frequens Gorka
Vekshinella crux (Deflandre & Fert)
Zygodiscus spiralis Bramlette & Martini

In Gebel Duwi, the *Nephrolithus frequens* Zone coincides with the planktonic foraminiferal *Globotruncana esnehensis* Zone giving rise to a Late Maastrichtian age.

5- *Markalius astroporus* Zone:

It is met with in the next 10 meters of Dakhla Shale overlying the *Nephrolithus frequens* zone at Gebel Duwi. Following Mohler & Hay (in Hay et al., 1967), this zone is defined as the interval from the first occurrence of *Markalius astroporus* (Stradner) to the first occurrence of *Cruciplacolithus tenuis* (Stradner).

It is characterized by the total extinction of the typical Late Cretaceous forms and the first appearance of diagnostic Tertiary coccolith assemblage. It was found to contain a somewhat badly preserved nannofossil assemblage, of which the following species are the most-common:

Cyclococcolithus gammation (Bramlette & Sullivan)
Markalius astroporus (Stradner)
Thoracosphaera imperforata Kamptner
T. operculata Bramlette & Martini

This is the lowest Tertiary nannofossil zone recognized by Hay & Mohler (1967) at Pont Labau, France. These authors remarked on the ubiquity of the marker species of this zone; namely *Markalius astroporus* (Stradner) and *Cruciplacolithus tenuis* (Stradner), pointing out that this zone should be found almost everywhere unless it is missing due to a hiatus. It also represents the lowermost Tertiary outcrop (sample 22/D) at Gebel Duwi. The base of this zone is marked by a disconformity and by the presence of reworked worn out; washed Upper Cretaceous forms such as:

Arkhangelskiella cymbiformis Vekshina
Coccolithus barnesae (Black)
Cretarhabdus crenulatus Bramlette & Martini
Cribrosphaerella ehrenbergi (Arkhangelsky)
Deflandrius intercisus (Deflandre)
Eiffellithus turriseiffeli (Deflandre)
Micula staurophora (Gardet)
Zygodiscus spiralis Bramlette & Martini
Zygolithus litterarius (Gorka)

This zone is equated with the lower part of the *Globorotalia compressa / Globigerina daubjergensis* zone of an Early Paleocene age.

6- *Cruciplacolithus tenuis* Zone:

It is recorded in the 25 meters of Dakhla Shale overlying the previously mentioned *Markalius astroporus* zone at Gebel Duwi. It corresponds to the basal 8 meters of Lower Owaina Shale member overlying the non-fossiliferous Black Shale capping the Sharawna Formation at Gebel Owaina. This zone is defined here by the first occurrence of *Cruciplacolithus tenuis* (Stradner) to the first occurrence of *Ellipsolithus macellus* (Bramlette & Sullivan). It is characterized by the total extinction of the typical Late Cretaceous forms, exhibiting the last occurrence of both *Arkhangelskiella cymbiformis* Vekshina and *Lithraphidites quadratus* Bramlette & Martini and the first appearance of diagnostic Tertiary coccolith assemblage. Such zone was found to contain a few nannofossil assemblages, of which the following species are the most common:

Coccolithus crassus Bramlette & Sullivan
Cruciplacolithus tenuis (Stradner)

Markalius astroporus (Stradner)
Thoracosphaera operculata Bramlette & Martini

As proposed by Mohler & Hay (in Hay *et al.*, 1967), this zone is defined as the interval from the first occurrence of *Cruciplacolithus tenuis* (Stradner) to the first occurrence of *Fasciculithus tympaniformis* Hay & Mohler. This might be subdivided into several distinct nannofossil zones as indicated by Hay & Mohler (1969), Martini (1970, 1971) and some others. Therefore it comprises the *Cruciplacolithus tenuis*, the *Chiasmolithus danicus* and the *Ellipsolithus macellus* zones of Martini (1970, 1971). In this study, such zone doesn't include *Chiasmolithus danicus* (Brotzen) which appeared later through the next *Ellipsolithus macellus* zone. Besides the occurrence of *Markalius astroporus* (Stradner) within the characteristic assemblage of this zone doesn't mean the presence of *Markalius astroporus* zone characteristic to the lowermost Tertiary.

The disconformity marking the base of this zone, is substantiated by the absence of the *Markalius astroporus* zone, in addition to the presence of a conglomeratic bed "sample 19/Ow" with reworked worn out, washed Late Cretaceous forms such as:

Arkhangelskiella cymbiformis Vekshina
Gretarhabdus crenulatus Bramlette & Martini
Cribrosphaerella ehrenbergi (Arkhangelsky)
Eiffellithus turriseiffeli (Leflandre)
Micula staurophora (Gardet)
Watznaueria barnesae (Black)

The zone under investigation is equated and runs parallel with the planktonic foraminiferal *Globanomalina compressa* / *Globigerina* *daubjergensis* zone of an Early Paleocene age. The next zone (*Ellipsolithus macellus* Zone, Fig. 3) is found to span the upper part of the *Gl. compressa / G. daubjergensis* zone, the *Praemurica uncinata* zone and the lowermost part of the *Morozovella angulata* zone, thus extending from Early to Late Paleocene.

A biostratigraphic correlation of the previously mentioned calcareous nannoplankton zones within the Late Cretaceous Paleocene succession in Upper Egypt is shown in Figure 4. The occurrences of the Egyptian nannobiozones recorded in the present study together with their thicknesses in meters are shown as follows:

Nannobiozones	Localities			
	Um el Ghanayem	G.Owaina	G.Duwi	Esh el Mellaha
6. *Cruciplacolithus tenuis* Zone	8.00	8.00	25.00	----
5. *Markalius astroporus* Zone	----	----	10.00	----
4. *Nephrolithus frequens*Zone	25.00	----	25.00	----
3. *Lithraphidites quadratus* Zone	10.00	32.00	----	34.50
2. *Arkhangelskiella cymbiformis*	15.00	16.00	35.00	12.50
1. *Quadrum trifidum* Zone	----	----	25.00	5.00

Nannofossil Classification

The rapid advances in the study of living coccolithophores and of nannofossils have virtually made every attempt at a suprageneric classification obsolete in a relative short time. Several attempts have been made in the past thirty five years, especially those of Stradner (in

Stradner, Adamiker & Maresch (1968), Gartner (1968), Bukry (1969), Perch-Nielsen (1985) & El-Dawoody (1990, 2000). Because of the limited, scope of the present study, however, any of these classifications will not be given, preference, The suprageneric assignment of the genera together with the index species recognized in this paper follows:

Outline of Classification Here Adopted

Phylum CHRYSOPHYTA

Class CHRYSOPHYCEAE

Order COCCOLITHOPHORALES SCHILLER, 1926

Suborder COCCOLITHINEAE KAMPTNER, 1928

Family Arkangelskiellaceae BUKRY, 1969.

Genus: *Arkhangelskiella* Vekshina, 1959

Arkhangelskiella cymbiformis Vekshina

Arkhangelskiella obliqua Stradner

Genus: *Kamptnerius* Deflandre, 1959

Kamptnerius magnificus Deflandre

Family Coccolithaceae KAMPTNER, 1928

Tribe Coccolitheae Kamptner, 1958

Subtribe Coccolithinae Kamptner, 1958

Genus: *Chiasmolithus* Hay, Mohler & Wade, 1966

Chiasmolithus bidens (Bramlette & Sullivan)

Genus: *Coccolithus* Schwarz, 1894

Coccolithus barnesae (Black)

Coccolithus crassus Bramlette & Sullivan

Genus: *Cruciplacolithus* Hay & Mohler, 1967

Cruciplacolithus tenuis (Stradner)

Genus: *Cyclolithella* Loeblich & Tappan, 1963

Cyclolithella robusta (Bramlette & Sullivan)

Genus: *Ericsonia* Black, 1964

Ericsonia subpertusa Hay & Mohler

Subtribe Cyclococcolithinae Kamptner, 1958

Genus: *Cyclococcolithus* Kamptner, 1954

PLATE I

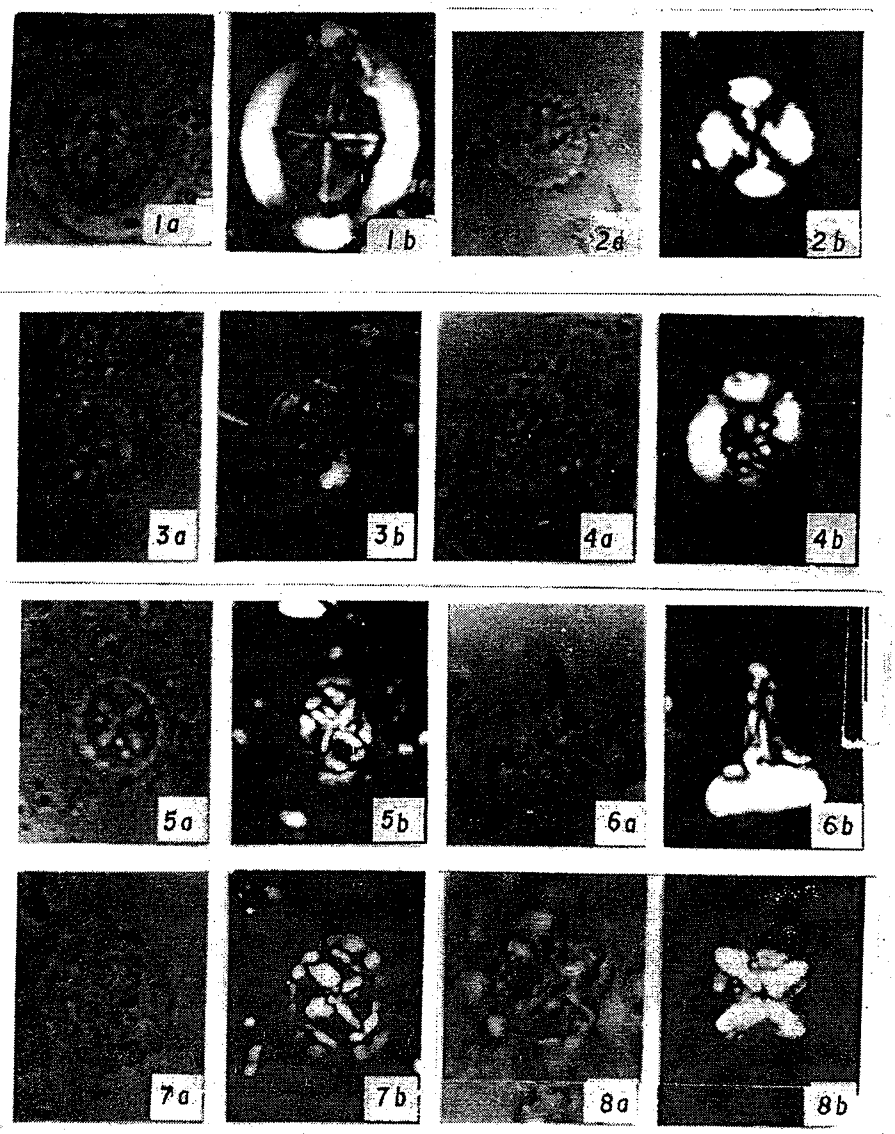


PLATE 2

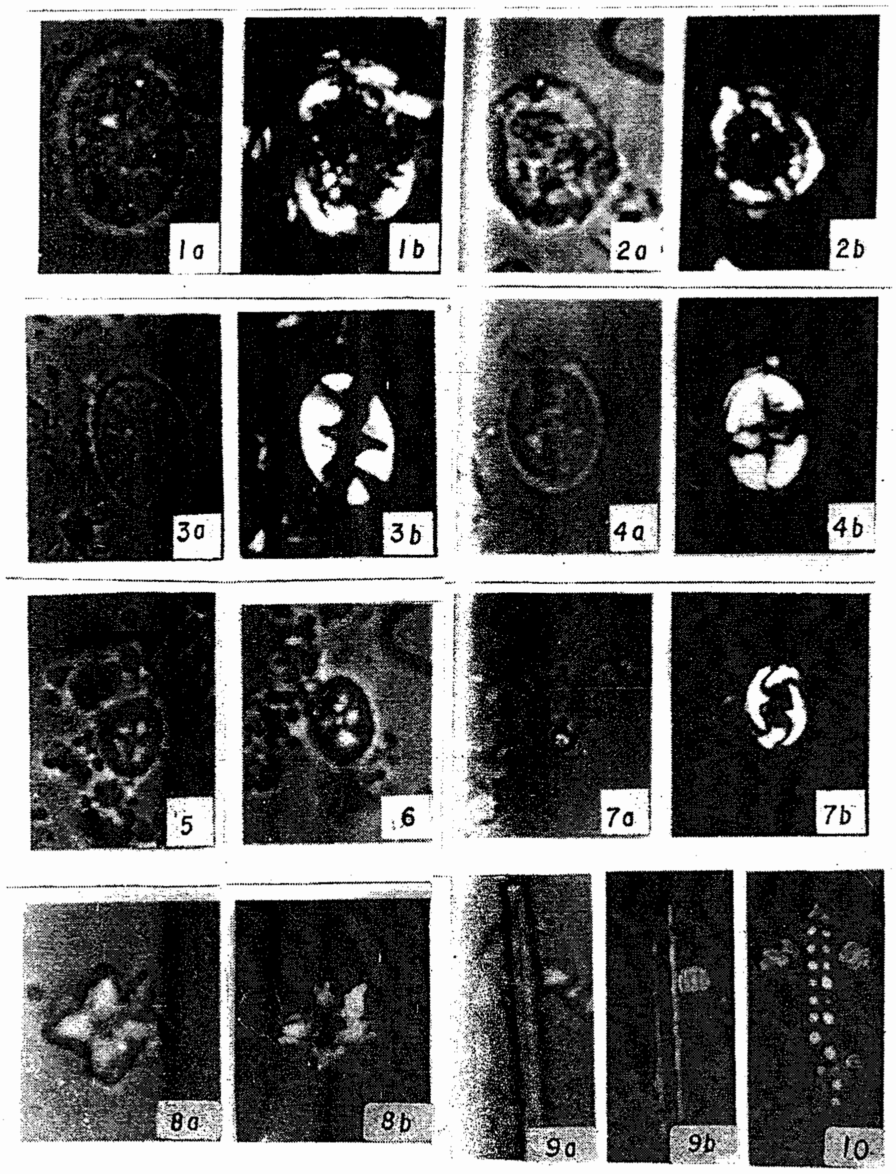


PLATE 3

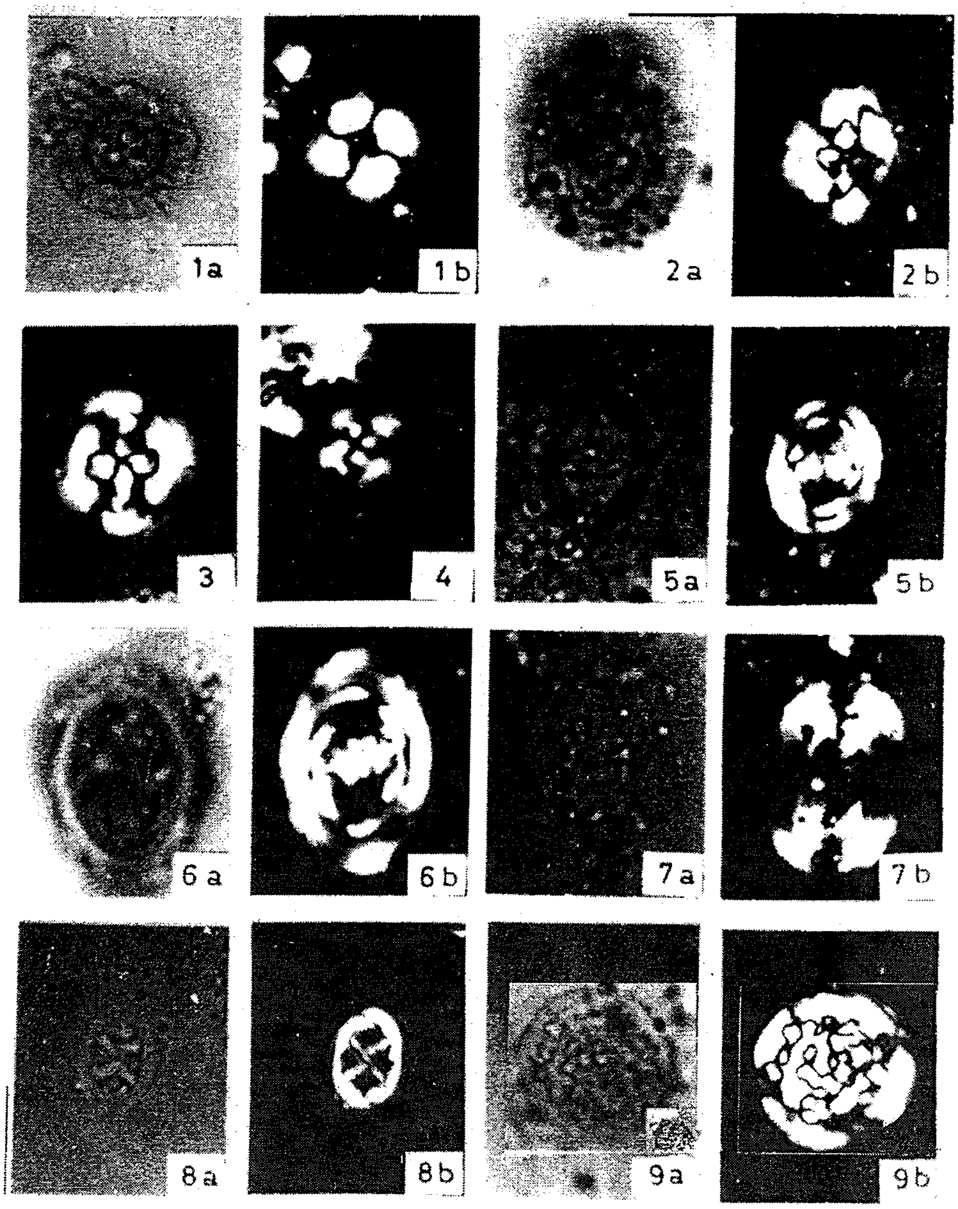
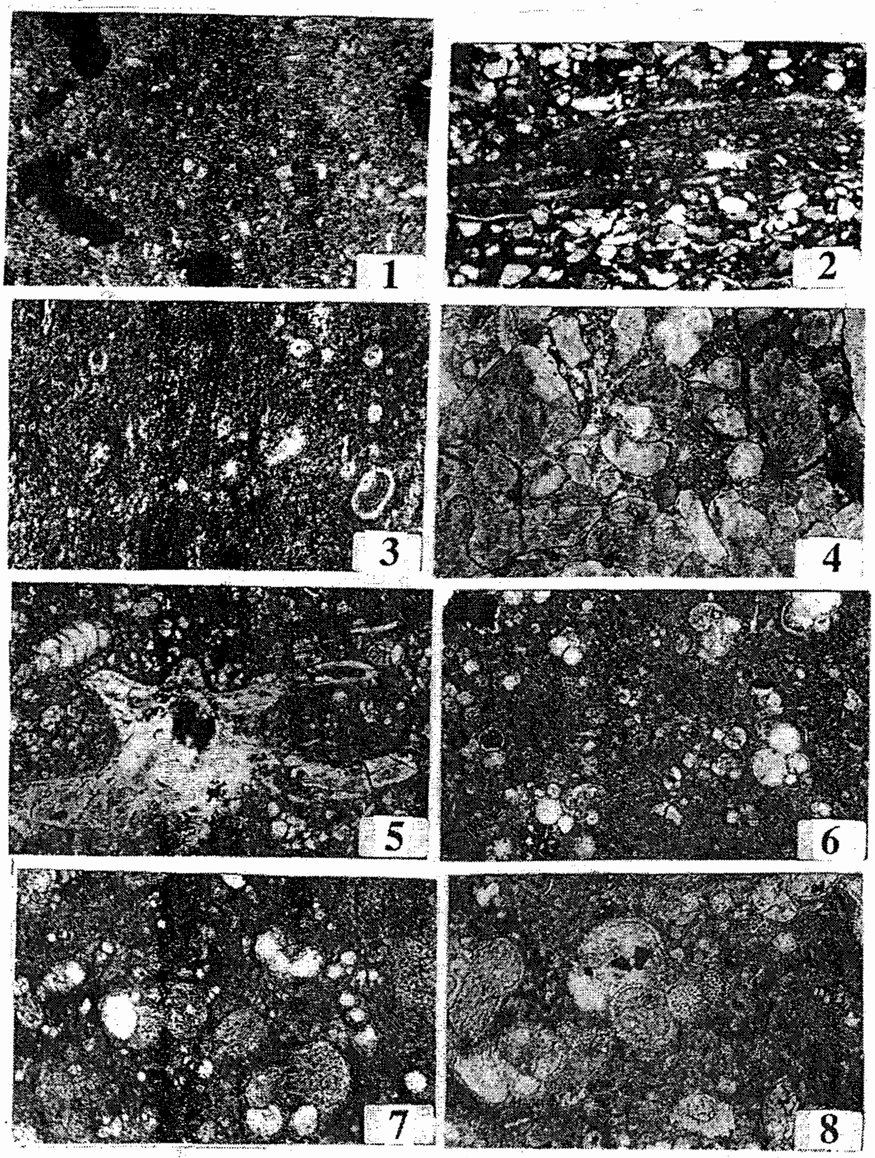


PLATE 4



Cyclococcolithus gammation (Bramlette & Sullivan)
Genus: *Markalius* Bramlette & Martini, 1964
Markalius astroporus (Stradner)
Subtribe Rhabdosphaerinae Stradner, 1968
Genus: *Cretarhabdus* Bramlette & Martini, 1964
Cretarhabdus conicus Bramlette & Martini
Cretarhabdus crenulatus Bramlette & Martini
Cretarhabdus romani (Gorka)
Genus: *Deflandrius* Bramlette & Martini, 1964
Deflandrius columnatus Stover
Deflandrius intercisus (Deflandre)

Tribe Cribrosphaerelleae Stradner, 1968
Genus: *Cribrosphaerella* Deflandre, 1952
Cribrosphaerella ehrenbergi (Arkhangelsky)
Genus: *Nephrolithus* GORKA, 1957
Nephrolithus frequens (Gorka)
Tribe Pontosphaereae Hay, 1966
Genus: *Pontosphaera* Lohmann, 1909
Pontosphaera multicarinata (Gartner)
Genus: *Ellipsolithus* Sullivan, 1964
Ellipsolithus macellus (Bramlette & Sullivan)
Tribe Zygosphaereae Kamptner, 1958
Subtribe Zygolithinae Stradner, 1968
Genus: *Eiffellithus* Reinhardt, 1965
Eiffellithus eximius (Stover)
Eiffellithus turriseiffeli (Deflandre)
Genus: *Heliorthus* Bronnimann & Stradner, 1960
Heliorthus concinnus (Martini)
Heliorthus distentus (Bramlette & Sullivan)
Genus: *Zygolithus* Kamptner ex Matthes, 1956
Zygolithus amphipons (Bramlette & Martini)
Zygolithus crux (Deflandre & Fert)
Zygolithus litterarius (Gorka)
Genus: *Zygodiscus* Bramlette & Sullivan, 1961
Zygodiscus adamas Bramlette & Sullivan

Zygodiscus pseudanthophorus Bramlette & Martini
Zygodiscus sigmoides Bramlette & Sullivan
Zygodiscus spiralis Bramlette & Martini
Tribe Calciosolenieae Kamptner, 1958
Subbribe Calciosoleniinae Kamptner, 1958
Genus: *Dictyolithus* Gorka, 1957
Dictyolithus tenuis Gorka
Family Thoracosphaeraceae SCHILLER, 1930
Genus: *Thoracosphaera* Kamptner, 1927
Thoracosphaera imperforata Kamptner
Thoracosphaera operculata Bramlette & Martini
Family Microrhabdulaceae DEFLANDRE, 1963
Genus: *Lithraphidites* Deflandre, 1963
Lithraphidites carniolensis Deflandre
Lithraphidites quadratus Bramlette & Martini
Genus: *Microrhabdulus* Deflandre, 1939
Microrhabdulus decoratus Deflandre
Microrhabdulus stradneri Bramlette & Martini
Incertae sedis:
Genus: *Micula* Vekshina, 1959
Micula staurophora (Gardet)
Genus: *Quadrum* Prins & Perch Nielsen, 1977
Quadrum trifidum (Stradner)

The following short comments and the selected synonyms are rather fragmentary. Besides, the stratigraphic ranges of the most common nannofossil species encountered here are introduced (Figs. 2, 3). Only the zonal nannofossil species are discussed herein.

Genus: *Arkhangelskiella* Vekshina, 1959

Arkhangelskiella cymbiformis Vekshina

(pl. 1, fig. 1)

1912 "Coccolith of unknown affinities" Arkhangelsky, pl. 6, fig. 24.

1959 *Arkhangelskiella cymbiformis* Vekshina, pl. 1, fig. 1, pl. 2, fig. 3.

Remarks: This species shows characters mentioned for the monotypic genus. The central area is divided into 4 quadrants by sutures subparallel to major and minor axes of the ellipse. Each quadrant is further subdivided by sutures at about 45° to the major and minor axes and secondary additional sutures. The perforations in the central area appear to lie along these sutures.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) deposits of Siberia. Abundant throughout the major part of the Maastrichtian Sharawna formation in Gebel Owaina. Few reworked specimens occur in the Paleocene conglomeratic bed of that locality. Individuals of this species are frequently present throughout the *Arkhangelskiella cymbiformis* zone at Gebel Duwi. Few specimens in the Paleocene strata are considered to be reworked because of association with few specimens of other Cretaceous forms.

Genus: *Cruciplacolithus* Hay & Mohler, 1967

Cruciplacolithus tenuis (Stradner)

(pl. 3, figs. 2,3)

1961 *Heliorthus tenuis* Stradner, p. 84, figs. 64,65.

1963 *Coccolithus helis* Stradner, in Gohrbandt, p. 74, pl. 8, fig. 16. pl. 9, figs. 1;2. "nom. subst. pro *Heliorthus tenuis* Stradner 1961, non *Coccolithus tenuis* Kamptner, 1937".

1967 *Cruciplacolithus tenuis* (Stradner) Hay & Mohler, p. 1527, pl. 196, figs. 29-31, pl. 198, figs. 1,17.

1968 *Chiasmolithus helis* (Stradner) – Locker; Monatsber. Deutsch. Akad. Wiss., 10: 223, pl. 1, figs. 3,4.

Remarks: Placoliths with two closely appressed shields, the broad distal shield is composed of about 40 dextrally imbricate segments, having almost radial sutures. Contral opening is spanned by rather robust crossbars along the major and minor axes. The orientation of the optical axis of calcite in the crossbars is normal to their length. This species seems to be related to the group of *Cruciplacolithus staurion* (Bramlette & Sullivan). The latter is however larger in size while its crossed central area is smaller.

Stratigraphic range; originally recorded in the Paleocene (Danian) deposits of Austria. In Gebel Owaina, it occurs commonly through the Lower Owaina Shale just overlying the Sharawna Formation. It ranges through the *Cruciplacolithus tenuis* and *Fasciculithus tympaniformis* zones, but it is found rarely and sporadically in the overlying zones at Gebel Duwi.

Genus: *Markalius* Bramlette & Martini, 1964

Markalius astroporus (Stradner)

(pl. 3, fig. 1)

1963 *Cyclococcolithus astroporus* Stradner, in Gohrbandt, p. 75, pl. 9, figs. 5-7.

1964 *Makalius inversus* (deflandre) Bramlette & Martini, (part) p. 302, pl. 2, figs. 4-6.

1967 *Markalius astroporus* (Stradner) Hay & Mohler, p. 1528, pl. 106, figs. 32-35, pl. 198, figs. 2,6.

1968 *Cyclococcolithus astroporus* Stradner – Radomski; Ann. Soc. Geol. Pologne, 38: 568, pl. 46, figs. 1,2.

Remarks: The photomicrographs of forms that were refered to *Markalius inversus* (Deflandre) by Bramlette & Martini in 1964 figs. 4-6, most closely resemble Stradner's figures of *Cyclococcolithus astroporus*. The other light and electron-micrographs of Bramlette & Martini represent *Ericsonia subpertusa* Hay & Mohler.

Stratigraphic range: Originally described from the Paleocene sediments of Austria. In Gebel Owaina, this species occurs through the Lower Owaina Shale and most of Middle Owaina Chalk characteristic to the Paleocene in many parts of the world.

Genus: *Nephrolithus* Gorka, 1957

Nephrolithus frequens Gorka

(pl. 2, fig. 2)

1957 *Nephrolithus frequens* Gorka; Acta paleont. Polon., 2: 263, pl. 5, Fig. 7.

Remarks: Such a species generally kidney – shaped. The rim is of two alternating rows of crystals intercalating each other. Central area occupied by ring – shaped structures composed of imprecating crystals of clock – wise orientation.

Stratigraphic range: Originally described from the Upper Cretaceous (Maastrichtian) of Poland. In Egypt, it occurs in Gebel Duwi, representing the zonal marker of the *Nephrolithus frequens* Zone of Late Maastrichtian.

Genus: *Lithraphidites* Deflandre, 1963

Lithraphidites quadratus Bramlette & Martini

1964 *Lithraphidites quadratus* Bramlette & Martini, p. 310, pl. 6, figs. 16, 17, pl. 7, fig. 8.

Remarks: Some specimens of *Lithraphidites carniolensis* Deflandre are somewhat thicker, more delicate and less elongate. These are short but have wider keels than long ones. They appear to grade into *Lithraphidites quadratus* Bramlette & Martini characterized by the abrupt tapering to pointed ends and the discontinuation of the keel to the tip of the specimen.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) of U.S.A. (Alabama), Denmark, France, Netherlands and Tunesia. This species is commonly restricted to the topmost part of Middle Sharawna Marl together with the overlying Upper Sharawna Shale in Gebel Owaina.

Genus: *Quadrum* Prins & Perch Nielsen, 1977

Quadrum trifidum (Stradner)

(pl. 1, fig. 8)

1961 *Tetralithus gothicus trifidus* Stradner, in Stradner & Papp, p. 124, text – fig. 23 (3).

1973 *Tetralithus trifidus* Stradner, Roth, p. 728, pl. 18, figs. 6, 7.

1977 *Quadrum trifidum* (Stradner). Prins & Perch-Nielsen, in Manivit et al., p. 178.

1977 *Quadrum trifidum* (Stradner). Verbeek, p. 123, pl. 12, fig. 11.

Remarks: Such a species has forms with three and with four elements, which start their range at the same level and are generally considered to belong to one species. The three and four armed forms of *Tetralithus gothicus* Deflandre are also found together. Because specimens with four arms are more frequent in Spain and those with three arms more frequent in Tunisia, it seems likely that the number of arms depended on ecological circumstances. For these reasons both forms are considered to belong to the same species.

Stratigraphic range: Originally known in the Upper Cretaceous (Maastrichtian) of France. This species is commonly restricted to the topmost part of the Duwi Phosphate denoting a Campanian–Lower Maastrichtian age in Gebel Duwi.

MICROFACIES STUDIES

The hard beds, which are unfavorable for any appropriate washing techniques, were thin sectioned and studied for their microfacies. A series of monographs were published dealing with microfacies of many parts of the world (Misik, 1966, Howritz & Potter, 1971, Scholle, 1978 and Flugel, 1982).

In Egypt, Omara (1955) was the first to introduce the facies analysis for the Upper Cretaceous and Basal Eocene sediments of the Nezzazat area. Several authors were engaged in the Cretaceous – Tertiary microfacies including: Barakat & Tewfik (1966), Ismail & Selim (1967), Ghorab & Ismail (1969), Barakat & El-Dawoody (1973), El-Dawoody & Aboul Karamat (1993) are the most prominent.

The terminology proposed by Folk (1962) and Dunham (1962) in describing the different carbonate rock types is followed here in the present study. Dunham's classification is essentially textural and is most valuable when used in a purely descriptive way for lithified rocks. Textural maturity is implied in that the least mature varieties are richer in mud matrix. However, depositional deductions based on these textural characters alone need great care.

In this study, the main bulk of the sampled beds examined are allochemical rocks (having > 10 % allochems). These are either microcrystalline allochemical rocks (in which the microcrystalline ooze matrix > sparry calcite cement) or sparry allochemical rocks (in which the sparry calcite cement > microcrystalline ooze matrix). If the rock includes a large proportion of organic remains, it is classified either as "Biomicrite" or "Biosparite" respectively. Biomicrosparite is a combination of both Biomicrite and Biosparite. Rocks consisting of microcrystalline ooze with 1 – 10 % scattered fossils are termed "Fossiliferous micrites".

The indurated interbeds were thin-sectioned and microscopically examined. The study of such rock samples was found necessary to throw more light on the evolutionary history of the sedimentation basin (Folk, 1959, 1962). The paleoenvironmental conditions that prevailed during sedimentation of the different lithostratigraphic units were interpreted.

1. Variegated Shale (Pl. 4, fig. 1)

Very fine grained, argillaceous matter, microcrystalline, with ferruginous streaks and irregular patches, slightly arenaceous and poorly micaceous, unfossiliferous. This facies is recorded at the basal part of Gebel Duwi.

Environment: Inner neritic, with relatively shallow water conditions, not far from a nearby landmass.

2. Sandy Shale (Pl. 4, fig. 2)

Highly siliceous, angular to subrounded sand grains, ill-sorted, with some phosphatic grains highly stained with iron oxides, and few glauconitic granules, unfossiliferous. This facies is known through the Duwi Phosphate (sample No. 3) in Gebel Duwi.

Environment: Shallow marine, where phosphatic materials have been accumulated.

3. Fossiliferous Micrite (Pl. 4, fig. 3)

Very fine grained, cryptocrystalline with undifferentiated organic remains together with some phosphatic grains, arranged nearly parallel to the direction of lamination. Such facies is found in the upper part of the Duwi Phosphate (sample No. 3a) at Gebel Duwi.

Environment: Neritic, with calm conditions of sedimentation "low agitated bottom conditions".

4. Phosphatic Biosparite (Pl. 4, fig. 4)

Mainly composed of phosphatic remains in the form of plates, granules and rounded bodies embedded in a groundmass of microcrysta-lline carbonates and in parts it is sparry calcite. Phosphatic granules are mostly well sorted and they exhibit straight extenction with micaceous inclusions. This facies is known in Duwi Phosphate formation, just below the uppermost phosphatic bed.

Such a type of association reflects an inner neritic environment that has been strongly affected by high level of energy caused by waves. Secondary crystallization may have taken place and gave rise to the sparry texture.

5. Phosphatic Blomicrite (Pl. 4, fig. 5)

Fine grained, highly fossiliferous, with benthonic foraminifera mainly represented byretaild forms together with well preserved phosphatic remains such as vertebrae and ribs. This facies caps the Duwi Phosphate of the Maastrichtian part in Gebel Duwi.

Environment: Mixed environment in which marine transgression gently overlapped the phosphatic bioherms.

6. Heterohelix Biomicrite (Pl. 4, fig. 6)

Microcrystalline, highly fossiliferous, with planktonic and benthonic foraminifera. The planktonics are mainly represented by *Heterohelix spp.*, *Globotruncana spp.*, globigerinas and globorotalias. The benthonics are represented by *Bolivina sp.*, together with rotalid forms and lagenid forms. Typical *Heterohelix* biomicrites are recorded from the Dakhla Shale formation at Gebel Duwi, samples 23/D – 25/D. Such a type of association reflects deep water conditions of warm sea with normal salinity where planktonic elements are the most abundant.

7. Globorotalia Biomicrite (A) (Pl. 4, fig. 7)

Fine grained and cryptocrystalline, highly fossiliferous with planktonic forams particularly Round-Keeled *Globorotalias* together with *Globigerina spp.* They are completely replaced by fine grained calcite filling up their interior cavities. Benthonic forams are also common and they are haphazardly distributed in the rock section. This facies is known in Dakhla Shale formation at Gebel Duwi, samples 20/D, 21/D.

Such a type of facies reflects deep water deposit of at least semi-pelagic character with abundance of planktonic calcareous microfauna.

8. Globorotalia Biomicrite (B) (Pl. 4, fig. 8)

Fine grained and cryptocrystalline, highly fossiliferous with planktonic forams such as sharp-keeled *Globorotalias* together with Round-keeled

Globorotalias, and few benthonic forams. This biomicrite represents a transitional phase between the round-keeled Globorotalias and the sharp-keeled globorotalias which characterize the advent of the Upper Paleocene fauna. It is known in Dakhla Shale formation at Gebel Duwi, samples 16/D–19/D. the last three samples are of a relatively low faunal content. This association reflects outer neritic to bathyal environment.

The following paragraphs are concerned with the relationship between the organisms met with in thin sections and their habitat medium. These paleoecological analyses elucidate the conditions under which sedimentation took place. Moreover, fossil organisms and the sediments in which they are embedded are frequently good indicators for the evaluation and adaptation of the organisms to the conditions that dominated during their life (Hecker, 1965).

Since this paleoecological study is based on wide spaced stratigraphic sections, measured and sampled from different localities, it is preferred to treat each section separately. The paleoecological conditions were interpreted for each section during a certain stratigraphic time and they are continued in another section for the next stratigraphic interval, till the whole investigated sequence is elucidated. The Duwi section embraces the stratigraphic interval between the Late Cretaceous and the Paleocene to the Early Eocene.

Late Cretaceous:

It is composed of multicolored shales, unfossiliferous, slightly to moderately sandy and phosphatic in part. These shales are intercalated by fine argillaceous and poorly fossiliferous calcareous interbeds. These lithological characters indicate deposition in a relatively shallow and stagnant or toxic bottom conditions that prevailed during the Campanian time. Shortly after the outset of the Maastrichtian in Duwi district, further shallowing took place resulting in the development of a lacustrine environment. This have been strongly affected by waves and current action and participated in the accumulation of phosphatic remains in the form of plates, granules and rounded bodies. Shallowing of the basin continued on, and the phosphatic beds have been deposited. Next to this phase, inundation took place and outer neritic conditions prevailed. This resulted in the formation of fine grained calcareous deposits rich in planktonic elements without contribution of coarse grained material from the dry land.

Paleocene:

By the advent of the Early Tertiary in Duwi district, a slight break is observed. It is noteworthy that the faunal break between the Late Cretaceous (Maastrichtian) and the Early Tertiary (Danian) is not accompanied by any facies change. Then marine facies dominated in both ages. This is probably due to sudden uplift by the close of the Cretaceous where no shallowing could be recognized. This movement was followed by a short period of erosion & abrupt inundation which lead to the formation of open marine facies in both Maastrichtian and Danian sediments. Similar sequence of facies, irrespective of aging, was pointed out in Ezz El-Orban area (Barakat & Fahmy, 1968).

The Danian time is characterized by open marine facies with abundant planktonic Foraminifera particularly the rounded-keeled Globorotalias together with other planktonic elements. This type of outer neritic facies dominated also in the Late Paleocene (Landenian) with the sharp-keeled Globorotalias embedded in a fine and cryptocrystalline argillaceous groundmass. Intertonguing of medium grained and holocrystalline carbonates were met with, however, it was found unfossiliferous. The open marine facies persisted throughout the whole Paleocene time characterizing the continuously subsiding basin during this episode.

SUMMARY AND CONCLUSIONS

The investigation of the Late Cretaceous Paleocene in the four surface sections in Upper Egypt: Esh el Mellaha Range and Gebel Duwi, Red Sea Coast, Gebel Owaina, Nile Valley and G. Um el Ghanayem, Kharga Oasis was undertaken. This led to the classification of such succession into the following rock stratigraphic units; arranged from top to base as:

Owaina Shale
~~~ 3- Dakhla Shale ~~~~
Sharawna Shale
2- Duwi Phosphate
1- Quseir Variegated Shale and Nubia Sandstone

These rock units have a regional distribution and are used as a basis for detailed mapping.

This succession was zoned on the basis of its nannofossil content. The proposed zones were correlated with those recognized in other parts of the world, arranged from top to base as:

6. *Cruciplacolithus tenuis* Zone
5. *Markalius astroporus* Zone

~~~~~~~~~~

4. *Nephrolithus frequens* Zone
3. *Lithraphidites quadratus* Zone
2. *Arkhangelskiella cymbiformis* Zone
1. *Quadrum trifidum* Zone

The study of stratigraphic ranges of the planktonic foraminifera found contemporaneous with these nannoflora in such succession aided in delineating five microbiostratigraphic zones. These zones were equated with the previously mentioned nannobiozones through a high-resolution biostratigraphy. Furthermore, both biostratigraphic zonations were correlatable with corresponding successions in other

parts of the world. This sort of study results in a number of interesting conclusions:

1. **A comprehensive nannopaleontologic study of the Late Cretaceous – Early Tertiary succession comprises a detailed taxonomy for the nannofossil assemblages recorded (El-Dawoody, 1978). This led to the identification of around 160 nannofossil species belonging to 25 genera in Duwi/Owaina sections, the most-common of which are related to the physical stratigraphy of the area under investigation through two clearly drawn distribution charts (Figs. 2, 3).**
2. **The lowest formations cropping out in the studied region are at Gebel Duwi/Owaina – Esh el Mellaha sections. These are the Variegated Shale and Phosphate formations which may be dated, on the basis of megafossils and of nannofossils rather than microfossils, as of Campanian – Maastrichtian.**
3. **The Sharawna Formation is of Maastrichtian age. It is characterized by two nannofossil assemblages representing a lower *Arkhangelskiella cymbiformis* Zone and an upper *Lithraphidites quadratus* Zone. The *Arkhangelskella cymbiformis* Zone falls within the *Gansserina gansseri* / *Heterohelix globulosa* Zone at Gebel Duwi, occupies the lower part of such zone in both Owaina and Um el Ghanayem sections to the west; all are of an Early-Middle Maastrichtian age. The *Lithraphidites quadratus* Zone occupies the upper part of *Gansserina gansseri* Zone in both Owaina and Esh el Mellaha sections, the two zones are of Middle-Late Maastrichtian age.**
4. **In Gebel Duwi, on the other hand, the *Lithraphidites quadratus* Zone disappears, due to the presence of an intraformational conglomerate, and the *Nephrolithus frequens* Zone directly overlies the**

Arkhangelskiella cymbiformis Zone. The disappearance of the topmost *Nephrolithus frequens* Zone toward the west is due to the presence of an intraformational conglomerate, but of higher level than those found in Gebel Duwi. This is achieved by the presence of incomplete *Globotruncana esnehensis* Zone at the topmost part of the Late Cretaceous at Gebel Owaina on the Nile Valley.

5. The Black shales capping the Sharawna Formation are barren in their microfossil and nannofossil contents, but with an arenaceous foraminiferal assemblage in few thin calcareous bands intercalating these shales. Such an assemblage marks the Maastrichtian (Late Cretaceous) in many parts of the world. The presence of a conglomeratic bed with reworked Maastrichtian fossils and some glauconites between the Maastrichtian and Early Paleocene in Gebel Owaina shows that uplift must have occurred at the end of the Late Cretaceous.
6. The Owaina Formation is differentiated into six calcareous nanno-plankton zones. The lowest three zones; the *Markalius astroporus*, the *Cruciplacolithus tenuis* and the *Ellipsolithus macellus* zones are characteristic to the lower Owaina Shale member. Again the *Cruclpiacolithus tenuis* Zone and lower part of the overlying *Ellipsolithus macellus* Zone are equated with both *Gl. compressa / G. daubjergensis* and *Praemurica uncinata* zones of an Early Paleocene age. (Fig. 4). The upper part of *Ellipsolithus macellus* zone and the overlying *Heliolithus kleinpelli* zones are easily correlatable with the *Morozovella angulata* zone denoting a Late Paleocene age.
7. It was possible from the litho- and biofacies studies to recognize the depositional environments of the different formations. The Late Cretaceous succession was accumulated under variable conditions. It

started with multi-colored shales reflecting shallow and stagnant or toxic bottom conditions. This is followed by lacustrine environment whereby phosphatic remains, organic granules and rounded bodies were allowed to settle down. Next to this phase, deepening took place and resulted in the formation of fine grained calcareous deposits.

8. The detailed correlation of the lithostratigraphic units as well as the nannoplankton zones and planktonic foraminiferal zones of the studied sections makes possible the more accurate correlation of other Late Cretaceous and Early Tertiary sections in Egypt.

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الطبقية الحيوية النانوسية ودراسات لسحنات تتابع الطباشيرى العلوى – الباليوسين بجنوب مصر

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يوضـــح هـــذا البحـــث أهمـــية الطبقية الحيوية للهوائم الكلسية الدقيقة التى سجلت من بعض صخور الطباشـــيرى العلـــوى–الباليوسين والتى جمعت من جنوب مصر. وأدت الدراسة الدقيقة لهذه الهوائم النباتية الجيرية وتواجدهـــا الطبقى إلى تحديد عمر محدد للوحدات الصخرية المختلفة بالإضافة إلى توضيح الطبقية الحيوية للنانوس والتى لا تزال غامضة إلى حد ما فى مصر. عرفت ست نطاقات حيوية، رتبت من أعلى إلى أسفل، كالاتى:

٦– نطاق	(*Cruciplacolithus tenuis*	
٥– نطاق	(*Markalius astroporus*	E. Paleocene
٤– نطاق	(*Nephrolithus frequens*	
٣– نطاق	(*Lithraphidites quadratus*	
٢– نطاق	(*Arkhangelskiella cymbiformis*	L. Cretaceous
١– نطاق	(*Quadrum trifidum*	

قورنـــت هـــذه النطاقات الحيوية على أساس الهوائم الكلسية الدقيقة بنظيراتها نطاقات الفورامينـــيفرا الهائمة الآتية – نطاق *Globotruncana esnehensis* ونطاق *Gasserina gansseri* ونطـــاق *Contusotruncana fornicata* لنفس التتابع. ووجد أن نطاقات *Praemurica uncinata* و *Globanomalina compressa / G. daubjergensis* تعلو التتابع بأكمله.

كما وصفت ثمان تجمعات للسحنات الصخرية وجد أنها تجمعت تحت ظروف مغايرة. بدأ الترســـيب بطفلة متباينة اللون تدل على أن الترسيب تم فى مياه ضحلة راكدة، تلى ذلك ظروف بيئية ترسبت خلالها رواسب الفوسفات بما فى ذلك الحبيبات العضوية المستديرة وفى النهاية زاد عمق البحر تدريجيا حيث نتج عن ذلك الحبيبات الدقيقة للرواسب الكلسية.